

**A feasibility study to move a significant fraction of
the ground data processing tasks associated with
NASA's Polar, Wind, and Geotail satellites and,
optionally, operations of the Polar and Wind
spacecraft to the University of Colorado's
Laboratory for the Atmospheric and Space Physics
(LASP)**

Prepared by R. Davis and W.K. Peterson

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**To Dr. R.A. Hoffman,
Polar Project Scientist
Code 696
Goddard Spaceflight Center
Greenbelt Md. 20771
E-mail: rhoffman@pop600.gsfc.nasa.gov
FedEx: Building 2, Room 224
303-286-7386**

Table of Contents	Page
Executive Summary	3
Introduction	3
LASP Capabilities for Mission and Science Operations of ISTP Missions	
Overview	4
Facilities	5
Computer Hardware and Communications	6
Personnel	6
Security	7
Software	7
Approach to Ground Data Processing	8
Ground Data Processing Tasks (Preliminary statement of work)	9
Estimate of costs of Ground data processing	12
Proposed Schedule for implementing ground data processing at Colorado	12
Approach to Operations	13
Operations tasks (Preliminary statement of work)	14
Estimate of costs of operations	19
Proposed schedule for implementing operations at LASP	20
Summary of tasks in the requirements document that LASP does not feel it can efficiently take on in the near term.	21
Summary of important qualifications	22
Summary of estimated costs	23

Executive Summary:

The University of Colorado's Laboratory for Atmospheric and Space Physics (LASP) has substantial experience in developing satellite mission operations and data systems. As outlined in the following section, LASP has operated five spacecraft. Two of the satellites (STRV-1A and STRV-1B) were built and initially operated in the UK. At NASA's request operations were successfully transferred to LASP. This transfer included a transition to the LASP developed and maintained OASIS-CC software package for real-time monitoring and control of spacecraft.

LASP has the facilities (including two fully outfitted operating rooms), infrastructure, and staff to take on the tasks outlined below with the addition of only a minimal amount of computing and storage capability. No new staff are required to support the activities proposed here. The existing staff is currently involved in preparations for two launches which has an impact on the schedule proposed here.

LASP has evaluated the project requirements document. We propose to implement the policies and procedures that were employed in the successful transfer of the STRV satellites to LASP control. We have identified tasks that can not be efficiently incorporated into the LASP structure. These tasks include the functions of the Flight Dynamics Facility (FDF) and Instrument and Spacecraft engineers. We have broken the requirements into two broad areas, ground data processing and operations. We are prepared to take on all or appropriate portions of the tasks described more fully below.

Summary tables of estimated costs and proposed schedules are included.

Introduction and motivation

NASA's Senior Review of Operating Satellite Projects in 2001 recommended the continued operation of full Polar Science Operations, and limited operations of the Geotail and Wind spacecraft. Responsibility and funding for continued operations of the associated ISTP Command and Data Handling Facility (CDHF) were transferred to the Polar Project Office and the ISTP office effectively disbanded. The funds for operations and data analysis were restricted and the Polar Project was encouraged to look for significant costs savings.

Polar investigators at the Laboratory for Atmospheric and Space Physics (LASP) at University of Colorado (Drs. Daniel Baker and W.K. Peterson) informed the Polar Project of the extensive experience of Randal Davis and his group in operations and ground data processing for NASA and the UK. A summary of LASP capabilities is given below.

Dr. Peterson at LASP as well as groups at NASA/Goddard (headed by Dr. Bob McGuire), UC Berkeley (headed by Peter Schroeder), and NASA/Marshall (headed by Dr. Dennis Gallagher) were encouraged by Dr. Robert Hoffman, Polar Project Scientist to work together to analyze and determine what portion of the operations and ground data processing task could be efficiently moved from the existing CDHF facility. A requirements document was formulated to provide a clear discussion of what tasks currently done by the CDHF, and other Goddard organizations must be continued in a timely and reliable manner.

Dr. Peterson participated in a series of discussions and data exchanges with Barbara Giles (Deputy Polar Project Manager), McGuire and Peter Schroeder to determine where the work could be done most efficiently. These discussions revealed different approaches to meeting the requirements outlined in the Requirements Document. No clearly preferable

approach was identified. We decided, therefore, to produce independent informal studies of the approach, schedule, and costs for various portions of the work to be performed at each institution, for evaluation by the Polar Project.

In preparing this feasibility study it became clear that the tasks outlined in the requirements document could be divided into “Ground Data Processing”, “Operations” and “Tasks that could not efficiently be performed at LASP.” The study reported here reflects this division. LASP is prepared to take on Ground Data Processing, Operations, or both. The tasks outlined in the requirements document that LASP does not feel it can efficiently perform are listed at the end with some words describing how we reached this conclusion.

LASP Capabilities for Mission and Science Operations of ISTP Missions

Overview

The University of Colorado’s Laboratory for Atmospheric and Space Physics (LASP) has substantial experience in developing satellite mission operations and data systems and in running all facets of spacecraft missions. Any ISTP spacecraft operations or science data system activities performed at LASP would build upon the solid foundation in place to support past and present missions.

As seen in Figure 1 below, LASP has operated five spacecraft: the Solar Mesosphere Explorer (SME) from 1981 to 1989; the Space Technology Research Vehicles (STRV-1A and STRV-1B) from 1996 to 1998; the Student Nitric Oxide Explorer (SNOE) from 1998 to present; and the Quick Scatterometer (QuikSCAT) satellite from 1999 to present. Two more spacecraft currently under development — the Ice, Cloud and Land Elevation Satellite (ICESat) and the Solar Climate and Radiation Experiment (SORCE) — will be operated by LASP after their launches in 2002. Figure 1 also shows that LASP has developed science data systems for major instruments (for example the UARS SOLSTICE and Cassini UVIS experiments), and entire spacecraft (SME, SNOE and SORCE). These science data systems provide for instrument planning and sequencing, data processing from Level Zero on up to final archive volume preparation, long-term data management, and tools for science data analysis and display.

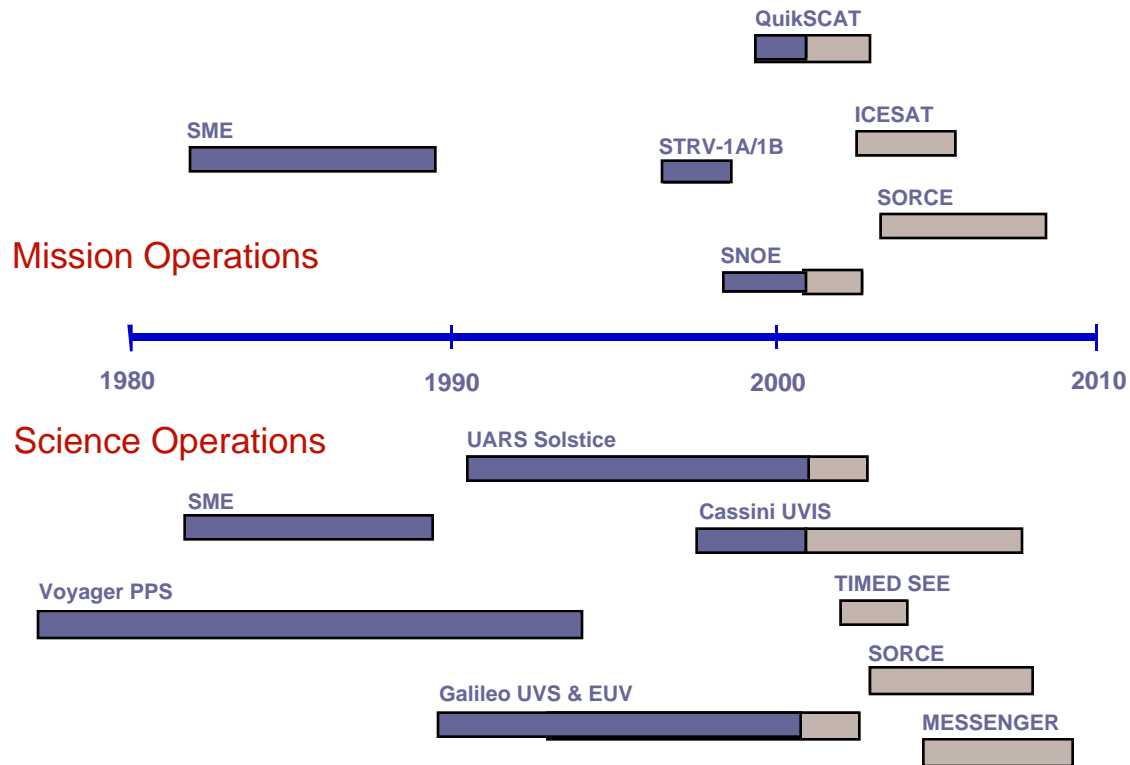


Figure 1 — LASP Heritage in Mission and Science Operations

LASP's experience with the twin STRV-1A and 1B spacecraft is germane to the transfer of ISTP operations. STRV-1A and 1B were built by the U.K. Defense Evaluation and Research Agency (DERA) and were operated from England for the first two years of their life. In 1996 the DERA planned to take their ground station offline for upgrades and were prepared to turn off the two satellites. NASA requested that operations be transferred to LASP instead, so that the two satellites could continue gathering data. This process was accomplished during the period May to September 1996. During the first four months LASP created a new mission operations system for the spacecraft using software that was already in place for SNOE and other missions. The transition occurred during September: at first DERA commanded the spacecraft while LASP only monitored telemetry; then LASP commanded the spacecraft while DERA monitored; finally, when all software and procedures were validated, DERA signed off and LASP controlled the satellites for the following two years. STRV-1A and 1B were in geosynchronous transfer orbits and the Deep Space Network was used for all communications with the satellites, which gives us confidence to handle ISTP spacecraft via the DSN.

Facilities

Any ISTP satellite operations or science data system activities performed by LASP would take place within LASP's existing 2,000 square-foot Mission Operations Center (MOC) located in the LASP Space Technology Research building in the University of Colorado Research Park in Boulder. The core of the MOC consists of the following, as shown in Figure 2 below: two mission operations rooms — MOR-1 and MOR-2 — for routine spacecraft operations; a Computer and Communications Room to hold data processing computers, database management servers, and communications equipment; and

an Engineering Operations Room (EOR) for use by the engineers and scientists who support operations activities. Not shown in Figure 2 are additional facilities for supporting mission-specific operations and science data system activities. No new facilities are needed to support ISTP activities.

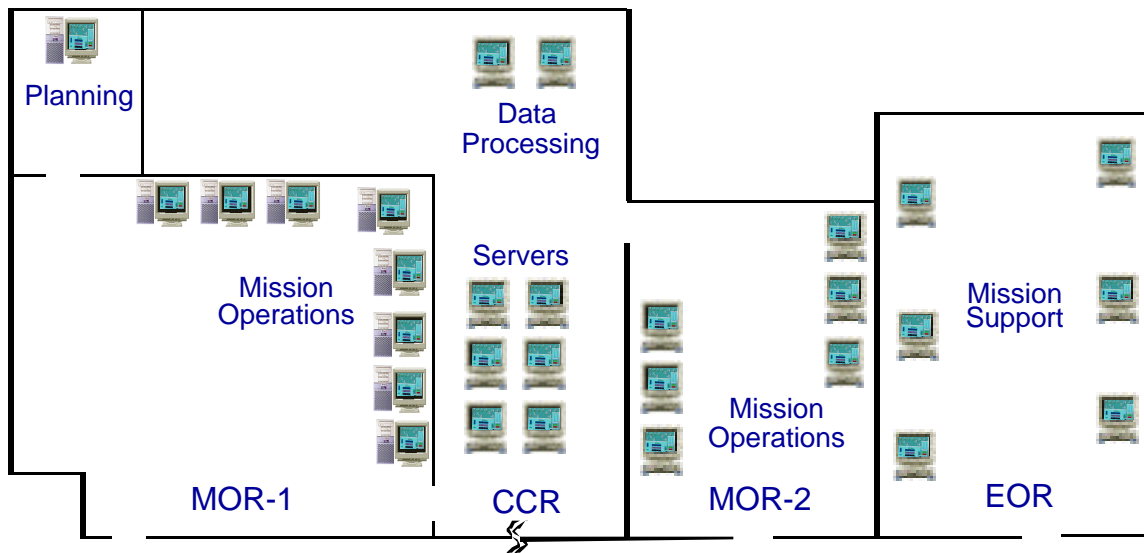


Figure 2 — LASP Mission Operations Center Core Layout

Computer Hardware and Communications

The LASP MOC is equipped with Sun workstations and servers and ISTP activities can use the systems that are already in place. However, an additional Sun workstation with CD-ROM writer would be necessary for some science data activities (cost about \$3K), and a small server might be needed to support satellite operations or science activities that require substantial online storage (cost of this server would run from \$11K to \$40K, depending on actual requirements).

Computers within the MOC are connected to one of three networks: the “Red Net”, which is highly secure, connects only to NASA’s Closed IONet and is used for real-time satellite operations; the “Blue Net” is secure and connects to NASA’s Open IONet and EMSn for support of non-real time satellite operations activities; and the medium-security “Green Net” connects to LASP’s local area network and the Internet for general operations support activities. No additional network connections are needed to support ISTP activities, although NASA might choose to implement a data line directly to JPL (our existing communications links all run through GSFC but can provide access to and from JPL). To support ISTP real-time operations, logical data paths would be created by NISN from the LASP MOC’s Red Net to the Special Function Gateway at JPL, which would provide command and telemetry access to Deep Space Network stations.

Personnel

Spacecraft operations and science data system activities at LASP are handled by the Mission Operations and Information Systems Division, which currently consists of 25 LASP professionals and three contractors, along with 25 student workers (both graduate and undergraduate level). Approximately half of these personnel make up the Flight Operations Team (FOT), which handles all satellite operations. The other half develop and maintain the scientific, engineering, and administrative data systems within the laboratory.

The FOT is a multi-mission team: the professionals and students work on all projects, not just one, and all personnel learn about all facets of a mission, not just a single area (like planning, or attitude determination).



Figure 3 — LASP Flight Operations Team During the SNOE Launch

No new personnel are needed to support ISTP activities. However, the FOT is currently absorbed in preparations for the upcoming ICESat and SORCE launches (along with ongoing operations of SNOE and QuikSCAT). As a result, the transition of any ISTP satellite operations activities to LASP couldn't begin until March 2003, although preparations of the needed computer hardware, communications systems, software, procedures, documentation, etc. could begin well before that.

Security

The MOC facility, the information systems within it, and the flight team personnel meet the same stringent security standards that apply to NASA's own satellite operations centers at GSFC and elsewhere. Documentation on LASP security — including Risk Assessment, Security Plan, and Rules of Behavior — as well as the results of recent NASA security audits can be made available for review by qualified ISTP project personnel.

Software

LASP has a mature software suite for satellite mission operations and science data processing that consists of LASP-developed software and commercial off-the-shelf software. LASP has been a major developer of software for mission operations and science data processing for many years. For example, LASP's OASIS-CC software package for real-time monitoring and control of spacecraft is one of the most widely used tools for satellite test and operations, with over 150 licensed users within NASA, the aerospace industry, and academia. This software is maintained to the highest standards. Most of this software has been designed for multi-mission operations and can be rapidly tailored for new applications, as was clearly demonstrated when we took over operation of the STRV-1A and 1B satellites in 1996.

LASP's plan for ISTP is to convert existing functions to run under the LASP software suite. For example, spacecraft real-time monitor and control would be converted to the OASIS-CC package, and scheduling and command generation activities would be converted to run under LASP's OASIS-PS software. This allows us to make ISTP activities as similar as possible to our existing missions, thus maximizing the effectiveness of our multi-mission flight operations team. Software tools that have been developed for other missions are available to convert ISTP spacecraft command and telemetry definitions

to the formats used by the LASP software and LASP has software to help convert procedures written in the Systems Test and Operations Language (STOL) to the C-STOL language used with the OASIS-CC software. We expect that these tools will allow us to adapt ISTP functions to work under LASP software reasonably quickly and efficiently.

Use of LASP software also opens up some new possibilities that we would like to explore with the experimenters for Polar and Wind. For example, experimenters could potentially monitor their instruments from their home institutions using the OASIS-CC software, which LASP would provide free of charge.

As mentioned above, the OASIS-PS software will be used for planning and scheduling, taking over functions currently performed using the CMS software and the OASIS-CC software for flight operations.

For flight dynamics, LASP has a full complement of Satellite Tool Kit (STK) software along with the MicroCosm software, which is a commercial version of the NASA Geodyne II program. LASP has significant experience and good working relationships with both GSFC's Flight Dynamics Facility and the JPL Multi-Mission Navigation group.

In the area of data management, LASP has developed general-purpose software for performing Level Zero data processing for both TDM and CCSDS formatted telemetry streams, along with flexible, table-driven software for decommutating telemetry data and constructing Level One data products. These tools would be used for any ISTP data processing that we might perform, although some of the software currently used in ISTP operations would likely be retained for producing specific data products. Many data management activities are performed using commercial Sybase database software. Oracle is also available. For engineering data analysis, LASP uses software written in the Interactive Data Language (IDL) to provide an easy way for project engineers and scientists to view spacecraft telemetry data and monitor spacecraft health and safety.

LASP has also developed a reliable and safe automated system for monitoring mission operations and science data processing activities so that "lights-out" operations are possible. As an example, there is one ground station contact the QuikSCAT spacecraft on each of its 14 or 15 orbits per day, but all but two of those orbits are performed in a totally automated fashion (the two exceptions are those orbits on which command upload sequences are sent to the satellite — those passes are always staffed by the flight operations team). We would expect to bring the same capabilities to bear for any ISTP operations. We realize that there are issues with the spacecraft, as well as the DSN, that make this somewhat difficult, but to get the true benefit of LASP's multi-mission operations capability, we need to automate these missions as much as we can.

Approach to Ground Data Processing

As noted above, LASP investigators have been involved in NASA-supported space research for over 40 years. They have participated in all types of NASA missions including building and operating two satellites SME (Solar Mesospheric Explorer) and SNOE (Student Nitric Oxide Explorer). Experience from these missions and participation in the Planetary Data System Project led to the development of an in-house software staff that is familiar with all aspects of operations and ground data processing. Particularly relevant for this feasibility study is the fact that this staff is currently finishing the preparations for the launch and LASP operations and ground data processing for two more satellites: SORCE (Solar Radiation and Climate Experiment) and ICESat (both, part of the Mission to Planet

Earth). In addition, in preparing for LASP ground operations and data process of the four SORCE instruments LASP has upgraded the network infrastructure and met NASA's newer and stricter security requirements for access to raw data from NASA centers.

Our approach then to migrating the above-noted data processing tasks to LASP is to start to transition the existing SORCE/ ICESat development team to Polar/Wind/Geotail ground data processing tasks early in 2002. This staff would investigate, plan, and then implement the code and procedures. Testing and validation would be done through a period of several weeks parallel operations.

Investigation would be done by two members of the team traveling to Goddard for a week to familiarize themselves with existing ground data processing tasks and acquiring as much documentation as possible. They would return and write a detailed outline of our implementation plan for review by NASA. This plan would be, in effect, a combined PDR/CDR. It would be circulated to Wind, Polar, and Geotail investigators as well as cognizant NASA personnel for their review and comments. No more than 4 weeks should be allowed for this review. Implementation, parallel processing, and transition would follow rather rapidly as indicated in the schedule below.

Our approach to the design will be to minimize the amount of "hands on" attention required to run the ground data processing system. We will rely on automated scripts and existing operational personnel currently employed. These operators are primarily undergraduate students with a supervisory layer of experienced software and operations professionals.

All work will be done under the supervision of R. Davis. Drs. Peterson and Baker will be consulted regarding interface issues, but not be involved in the detailed development, operations or supervision of the effort.

NUMBERS BELOW REFER TO SECTIONS AND PARAGRAPHS IN THE REQUIREMENTS DOCUMENT.

Selected Ground Data Processing Tasks that can be efficiently performed at LASP. (Preliminary Statement of Work)

1: Science Operations Planning

1.2: Predictive and Definitive Orbit Information:

Obtain 70 day predictive orbits and attitude for Polar, Wind, from Goddard Flight Dynamics Facility in TBD formats and similar data from Geotail in TBD formats on a scheduled basis.

Convert these data to CDF formatted files and Package in 70 day and 1 day CDF files. Because of the complexity of maintaining CDF/SFDU data pairs and the lack of documented uses for the associated SFDU files, we WILL NOT produce the associated SFDU files. There will be 9 different file types (3 satellites po_/wi_/ge_) and three orbit attitude types (_or_pre, _at_pre, _or_lng)

Obtain Geotail definitive orbit and attitude data from ISAS in a TBD format, convert them to CDF formatted files and package them into ge_ or_def, ge_at_def files.

Associated SFDU files *will not* be produced.

We *will not* produce Polar deapsun platform attitude data files, predictive or definitive. These files are used by the three imaging investigator teams, require specific and detailed knowledge of the platform operation and operational history. Production of these files is best done by one of the imaging teams.

If the responsible NASA officials determine that the predictive orbit and attitude data are inadequate for data analysis, we will process and distributed updated versions of attitude and orbit files as required.

1.3. Polar Despun Platform Pointing Planning.

We will work with the group or individuals who generate the Polar despun platform planning files to ensure that they have timely access to the Polar orbit and attitude files required for their work. These files are used by the three imaging investigator teams, require specific and detailed knowledge of the platform operation and operational history. We *will not* produce them.

3.6 Continuation of Quicklook data products:

The Quicklook (QL) data product is a direct generation of a level zero file from a tape recorder dump. The tape dumped recorder data are physically located at JPL and, with appropriate notification, can be pulled to the ground data processing center. The same software that produces 24-hour level zero data files can produce quick look data files. QL data product differs from the LZ data product only in the file name, start and stop UT (i.e. not generally 00:00), and extra work required to obtain the data from JPL.

We will develop the capability of providing QL data products for all Polar and Wind(not Geotail) instruments from tape recorder data . We will provide this service **ONLY** at the request of Dr. R.A. Hoffman to support instrument anomalies and public relations imaging sequences. The costs outlined below assume that only a few (~10) such requests will be made annually.

We will provide the QL data files on line or by e-mail to pre-designated recipients.

3.7 Data processing, Archiving and Distribution

We will work with JPL and NASA/Goddard to adapt existing procedures for transfer of telemetry files of Polar and Wind level zero data by ftp to computers at LASP.

We will develop procedures to acquire from the Polar and Wind operations center at LASP or elsewhere near real time level zero data as a backup to the level zero data from JPL. These files will be used to fill gaps in tape recorder dumps or other anomalies in the data stream from JPL

We will work with ISAS and Goddard to adapt existing procedures for transfer of telemetry files from Geotail by ftp to computers at LASP.

We will adapt existing codes and procedures provided by Goddard to assemble 24 hour telemetry files for Polar, Wind, and Geotail from spacecraft tape recorder dumps, near real time (nrt) pass data, and ISAS (Geotail). We will make a best effort to provide quality checking but will rely primarily on PI teams for quality validation.

We will produce the following LZ data products for

Polar: cep, efi, hyd, mfe, pix, pwi, qaf, scr, tid, tim, uvi, vis

Wind: 3dp, epa, kon, mfi, qaf, scr, sms, swe, tgr, wav

Geotail: cpi, efd, epi, hep, lep, mgf, pwi, qaf, scr

We will provide limited capability for re-processing

We will adapt existing software to make the following attitude files, but not the associated SFDU files currently produced on the CDHF:

po_k0_spha

wi_k0_spha

ge_k0_spha

To minimize operational complexity, we will maintain files for each data product in only one (1) format. For this reason *we will not* produce sirius level zero files for Geotail or associated SFDU files for any data products.

We will maintain _or, _at, _lng, _lz, and _spha data files on a server for remote “pull down” by PI teams. We will provide approximately 30 days of the larger _lz files and approximately 90 days of the other files on line. This server will have only a modest level of security. In particular no provision will be made for restricting access to data types by PI group.

We will provide a modest level of data backup and archiving. In particular we will make two full sets on CDROM (or possibly DVD's) of all data products produced at LASP. One set will be sent to NSSDC for archiving and one set retained locally for backup. No attempt will be made to make sure that all data files for a given day appear on the same physical CDROM. We will maintain an index, in simple ASCII listing format, of data names (including date information) on each CDROM.

After 30 days, primary access to LZ data products will be through the NSSDC deep archive.

3.8 Spacecraft Health and Safety Data processing:

This section of the requirements document is redundant. the types of spacecraft health and safety data products (qaf, scr, and spha) mentioned are discussed in section 3.7 above.

3.9 KP Generation:

The po/wi/ge k0_spha files are named as key parameter files. They are actually attitude files and will be produced and distributed as discussed in other sections. Other Key Parameter (KP) files are instrument specific. In particular they require a detailed knowledge of the instrument and its operational history. These data products are best produced by groups with easy and direct access to the many individuals holding undocumented knowledge about the state and operation of the various instruments. We will not undertake the difficult and complex task of porting existing KP software to a new environment.

3.10 Definitive orbit and attitude data:

As discussed in the requirements document, definitive orbit and attitude data for Polar and Wind were discontinued as part of an earlier re-engineering effort. If the responsible NASA officials determine that the predictive orbit and attitude data are inadequate for data analysis, we will process and distributed updated versions of attitude and orbit files as required.

As discussed in section 1.2 above, we will produce and distribute definitive orbit and attitude data from inputs provided by ISAS.

3.12 Data Distribution:

We will acquire command history logs from the Polar and Wind spacecraft operations group and make a modest effort to acquire the same information from the Geotail operations group. We will format these data in a tbd format, not necessarily identical to the format that has been used and provide them on line.

As discussed in section 3.7 and 1.2 we will provide an ftp server or equivalent with 30 days of large files and 90 days of small files, (including command history files) where PI teams can access and "pull down" data they require. Note: we *will not* support "pushing" files to PI sites using scripts running at LASP. We will provide access to all files to all persons authorized by individual PI's. It will therefore be possible for anyone with access to the server to pull down data from all Polar, Wind, and Geotail investigations.

We will make Custom LZ data distributions for TIMAS and CAMMICE/CEPPAD.

The two copies of TIMAS custom CD will contain all of the following data files for approximately 4 days per CD : po_tim_lz, po_scr_lz, po_k0_spha, po_or_pre, and po_at_pre .

The two copies of the custom CAMMICE/CEPPAD CD will contain all of the following data files for approximately 3 days per CD: po_cam_lz, po_cep_lz, po_scr_lz, po_at_pre, po_or_pre, po_ko_spha.

The format of these CD's will be discussed with the PI's involved and will not necessarily be the same as CD's currently provided by the Project.

We will distribute these custom CD's by snail mail.

On request of , and with appropriate supplemental funding from, the Polar project scientist, we will make similar custom CD's to other Polar PI teams.

Estimate of costs of Ground data processing

Costs are shown here as man-months (mm), man-weeks (mw) or full time equivalents (FTE). A summary and translation to \$'s is given at the end of this study.

Development:

1.2 Develop procedures and adapt existing software to obtain and reformat Polar, Wind, and Geotail orbit and attitude files	1 mm
1.3 Despun platform planning interface	1 mw
3.6 Quicklook data products	1 mw
3.7 Data processing archiving and distribution	3 mm
3.12 Custom CD's for selected Polar Investigators	1 mw
Sub Total	5 mm

Validation/Transition:

1.2 Validate orbit and attitude file generation	1 mw
1.3 Despun platform planning interface	nil
3.6 Quicklook data products	1 mw
3.7 Data processing, archiving, and distribution	1 mm
3.12 Custom CD's for selected Polar Investigators	1 mw
Sub Total	2 mm

Production Processing:

1.2 Orbit and attitude processing	included in 3.7
1.3 Despun platform planning interface	nil
3.7 Data processing archiving and distribution	1/2 FTE
3.12 Custom CD's for CAMMICE/CEPPAD and TIMAS	none
These will be produced by W.K. Peterson under his existing Polar/TIMAS data analysis grant.	
Sub Total	1/2 FTE

Travel Costs: 2 people 1 week at Goddard	~5k\$
On going materials costs	~5k\$/year
Required additional hardware:	~3k \$
Our current estimate is that we require a CD/DVD burner and some additional data storage, and a new CPU for CD production	

Proposed Schedule for implementing ground data processing at Colorado under two assumptions

1: Assuming operations are transitioned to LASP

Software Development starts	2/1/2002
Software Implementation plan distributed	3/1/2002
Software Implementation completed	8/1/2002
Validation/Transition begins	8/1/2002
Transition to LASP ground data processing	10/1/2002

2: Assuming operations *are not* transitioned to LASP

Software Development starts	2/1/2002
Software Implementation plan distributed	3/2/2002
Software Implementation completed	6/1/2002
Validation/Transition begins	6/1/2002
Transition to LASP ground data processing	8/1/2002

Approach to Operations

As noted several times above, LASP investigators have been involved in NASA supported space research for over 40 years. Particularly relevant for this proposal is the fact that this staff is currently finishing the preparations for the launch and LASP operations and ground data processing for two more satellites: SORCE (Solar Radiation and Climate Experiment) and ICESat (both, part of the Mission to Planet Earth). In preparing for LASP to operate these missions LASP has upgraded the network infrastructure and met NASA's newer and stricter security requirements for access to raw data from NASA centers.

Our approach to migrating the operations tasks to LASP is to start to transition the existing SORCE/ ICESat development team to Polar and Wind Operations tasks as soon as they become available and make the transition to Polar and Wind Operations at LASP after operations of SORCE and ICESat are well established. Beginning operations earlier would require a significant augmentation of the operations and development staffs. We do not want to assume the uncertainties and risks of a major staff expansion during the critical time we are beginning SORCE and ICESat operations. On the other hand, assured follow on work for the development staff will be a powerful morale booster that will better position us to retain the highly skilled software and operations personnel in the very competitive Boulder/Denver area markets. The proposed schedule below reflects the fact that software people will be available in early 02, but our commitment to SORCE and ICESat precludes beginning the transition to LASP operations until March, 2003.

Our implementation strategy is to investigate, plan, and then implement the code and procedures. Testing and validation would be done over a period of three months during which parallel operations would be performed at LASP and Goddard.

Investigation would be done by three separate two member teams traveling to Goddard for a week to familiarize themselves with existing operations tasks and acquire as much documentation as possible. They would return and write an detailed outline of our implementation plan for review by NASA. This plan would be, in effect, a PDR (preliminary design review). It would be circulated to Wind and Polar investigators as well as cognizant NASA personnel for their review and comments. No more than 4 weeks should be allowed for this review. Implementation would then proceed with monthly status reports being made to the NASA monitors. Towards the end of the implementation period, training materials for the student operators will be developed. At the completion of software

implementation, and before the interval of parallel processing, we would host a site visit by NASA personnel and current Goddard operators. During this visit we would make an extensive presentation of our operations plan. This would be a combination CDR and Pre-ship review. If no significant action items are identified, parallel operations will begin. In the first month of parallel operations, we will start with Wind (the easier of the two) only, then Polar only, with primary responsibility for safe operations remaining at Goddard. At the end of the first month we will host a second site review at LASP for final sign off on transition of operations to LASP. We will then begin parallel operations of both Wind and Polar, with Goddard participation shifting from primary to secondary and finally back up. This transition period *must* include one orbit trim maneuver for Wind and a flip or orbit trim maneuver for Polar. Depending on the exact phasing of the transition, it may be necessary to extend the operation of the Goddard operations center in back up mode until 10/03 as noted in the proposed schedule below.

Our approach to the design will be to minimize the amount of “hands on” attention required. We have determined that the current Polar/Wind operations environment and in particular the CMS (command management system) are too labor intensive and too incompatible with existing LASP operations software and philosophy to be retained.

As noted above, the LASP team has developed and maintains the OASIS-CC operations software used by many spacecraft operations shops. The OASIS-CC system address the same requirements as the exiting operations environment but does it with less computer power and most importantly less operator intervention.

We will rely on automated scripts and existing operational personnel currently employed. These operators are primarily undergraduate students with a supervisory layer of experienced software and operations professionals.

A particular strength of the LASP operations is that ongoing training is fundamentally built into the system because of the demands of educating the constant flux of student operators that pass through the system. This means that we have well documented software, procedures, and policies we rely heavily on.

All work will be done under the supervision of Randal Davis. Drs. Peterson and Baker will be consulted regarding interface issues, but not be involved in the detailed development, operations or supervision of the effort.

Operations tasks that can be effectively performed at LASP (Preliminary Statement of Work):

1. Science Operations Planning

1.4. Submission of Commanding sequences by instrument team.

We will obtain and adapt, existing documentation, code and procedures and implement them to run on LASP computers to support the following Operations Planning tasks.

- Obtain e-mails of commanding sequences from PI teams and strip headers

- Obtain the polar platform pointing plan from platform team

- Obtain eclipse times from FDF

- Obtain parameters for flip and attitude maneuvers from FDF and Polar and Instrument Engineers at GSFC

- Obtain information about battery health and safety

- Obtain requirements from Spacecraft and Instrument engineers about requirements for special operations.

Merge commanding sequences from the above inputs. Specifically we will develop daily commanding lists and provide them in a timely manner to the spacecraft and instrument engineers at Goddard for validation. If validation is not received in a timely manner, we will implement backup commanding sequences using predetermined procedures to ensure that the spacecraft and instruments are not compromised.

We will generate command history logs and provide them to the data archive in a tbd format.

We *will not* use the existing CMS system. We will work with the current operations staff to extract the most important “rules” captured in this system and implement them in our OASIS-CC software described above.

The primary SORCE for assistance to PI teams in building commands in response to instrument anomalies will remain with instrument engineers at Goddard. We will work with the instrument engineers and PI teams as required to generate new command sequences in response to instrument anomalies.

2. Flight Operations Planning

2.1 Preparation of spacecraft and instrument commanding sequences

We will provide procedures for PI teams to transfer validated instrument specific memory loads to be sent to their instruments in real time. We will support the intensive uploading requirements of the Polar VIS instrument, and emergency uploading requirements of other investigators within the resources available to us.

We will set in place procedures to ensure that all upload command sequences have been validated by Polar and Wind engineers all located at NASA/Goddard, and supported.

Geotail commanding and operations will continue to be performed by ISAS.

2.2 Spacecraft Ranging Information

Adapt or develop codes and procedures to provide tbd data in tbd format to the flight dynamics facility (FDF) at Goddard so they can develop ranging information for Polar Wind . Spacecraft ranging information for Geotail comes from ISAS.

2.3 DSN Scheduling

We will adapt existing procedures to develop and implement work with DSN to develop Polar/Wind DSN scheduling for Polar and Wind operations.

We will keep on-line logs of contact times on a web site accessible to Polar and Wind PI's so they can efficiently plan their infrequent near real time commanding sessions.

If specifically requested by NASA we will investigate what additional effort is required to perform the DSN scheduling task for Geotail operators physically located in Japan.

2.4 Special Operations Planning Scheduling

We will work with Polar Instrument engineers at GSFC and Polar PI's to develop flip plans for 3/02 (half flip to ecliptic normal) 9/02 (half flip to orbit normal), 3/03 (full flip) 10/03 (half flip to ecliptic normal) and thereafter at regular intervals to develop plans and procedures for trim maneuvers to maintain Polar in an ecliptic normal attitude.

We will develop and submit for review command sequences to implement maneuvers to cognizant engineers at Goddard .

We will work with WIND Engineers and PI's to develop and implement for orbit trim maneuvers.

We will adapt and implement existing plans and procedures for dealing with spacecraft and instrument emergencies .

We will schedule regular teleconferences with Goddard engineers to make sure emergency response plans are current.

We will work with Instrument and Spacecraft Engineers at Goddard to analyze instrument and spacecraft anomalies and develop plans to resolve them.

We will maintain emergency contact information for PI teams as well as for cognizant Polar and Wind spacecraft engineers at Goddard.

3 Flight Operations

3.1 DSN Contacts with the Polar and Wind Spacecraft

We will support one (1) scheduled Polar commanding session per day. We will, within the resources available to us, support emergency operations when instrument or spacecraft health and safety require it.

We will support one (1) Wind commanding session per week. We will, within the resources available to us, support emergency operations when instrument or spacecraft health and safety require it.

We will work with the Polar spacecraft engineer at Goddard on tape recorder management issues to minimize the number of Polar data download sessions per day. We will start with the current three Polar download sessions per day.

We will support one (1) or fewer Wind data downloading session per day and three (3) or fewer Polar downloading sessions.

The budget below is based on the existing rate of 1 contact for Wind per day and four for Polar.

We will work with Polar Engineers and DSN staff to develop “lights out” automated procedures for Polar and Wind data dumps. As noted in the “Approach” section below, many of the LASP operations staff live within 15 minutes of the LASP operations facility, and the existing automated paging software can be easily adapted to get operators in to handle “problem” Polar contacts. We recognize there will be some loss of Polar data. We will monitor and report data acquisition loss on a percentage basis weekly. We understand that the requirement is for 90% recovery and that, for short periods 80% recovery is acceptable. When the monthly average recovery rate falls below 90% we will produce a report for NASA outlining the reasons for and suggest, where appropriate, additional resources to improve the data acquisition rate.

To validate the LASP operations software and hardware, we will develop and implement a three month transition plan. It will begin with parallel operations at LASP and Goddard with primary control at Goddard. It will end with full operations being performed at LASP.

3.2 Spacecraft Engineering Health and Safety

We will obtain information from current Polar and Wind operations documentation and operators on the telemetry words used to determine instrument health and safety. We will implement these “monitoring points” in our OASIS-CC control software to monitor health and safety of Polar and Wind SC during initial and final phase every of contact.

There is no commanding or monitoring requirement for Geotail

As noted in section 2.4 above we will translate existing plans for anomaly response in place at Goddard and implement them when out of limits conditions are encountered.

We will report instrument and spacecraft anomalies to the cognizant PI representative as well as the designated spacecraft engineer and NASA contacts by phone as rapidly as possible. We will follow up with a written report distributed by E-mail within one week

If the out-of-limits conditions encountered are not covered by existing contingency plans, we will work with Spacecraft and instrument engineers at Goddard to develop and implement response plans. If appropriate we will include affected PI teams in the response planning effort.

We will provide a summary report of monthly operations activity to cognizant NASA managers by e-mail and maintain the report on a web site accessible to everyone.

3.3 Payload Engineering Health and Safety

We will obtain information from current Polar and Wind operations documentation and operators on the telemetry words used to determine instrument health and safety. We will

implement these “monitoring points” in our OASIS-CC control software to monitor health and safety of Polar and Wind SC during initial and final phase every of contact

We will monitor of all Polar and Wind instruments during each contact to ensure that all identified “monitoring points” are within limits. We will report instrumental out of limits conditions (anomalies) by phone to one of the individuals identified as a PI instrument contact. We will also notify by phone a designated Polar or Wind contact person at Goddard. We will follow up with a written report of the out of limits condition by e-mail within one week.

We will support nrt commanding sessions by PI teams for routine instrument maintenance or in response to instrument emergencies.

We will follow procedures currently in place for sending PI commands to their instrument. Specially, commands are to be provided by FAX or E-mail to the LASP operations center. The timing and/or order of commands can be changed by verbal notice during the contact, but no new commands will be constructed in response to verbal instructions.

3.4 Maintenance of Instrument GSE's:

Polar/CAMMICE/CEPPAD and Polar/VIS instruments currently use PI-provided GSE's physically located near the Goddard Polar/Wind operations center. These GSE's are provided the full Polar Level 0 data stream connected to the near real time data stream through a “rack” of equipment connected to the operations console. Access to the GSE's by the CAMMICE/CEPPAD PI's is by dial-in modem. Moving the “rack” of equipment and interface from Goddard to LASP is possible, but it will involve at best a significant “down” period during which it will not be possible to access the GSE's. We will therefore work with the VIS team at the University of Iowa and the CAMMICE/CEPPAD team at The Aerospace Corporation to provide the functionality currently provided by their GSE's at Goddard.

For the VIS team this GSE interface is a backup for times when the nrt data server (see section 3.5) below is not available. As noted below, we institute procedures and train all LASP operations personnel to verify that the Polar and Wind nrt data server is operating correctly before every commanding session. A reliable nrt data stream is important to all Polar and Wind investigators. LASP personnel are committed to making the nrt data stream more reliable than it currently is. We will work with the VIS investigators to determine their requirements for uptime and probably be able to provide it, thus eliminating the VIS requirement for a GSE.

For the CAMMICE/CEPPAD team, the GSE is the primary interface to the nrt data stream required to support instrument operations. It is unclear which is the harder and/or riskier task for the CAMMICE/CEPPAD team. A) Reengineering their GSE to accept the nrt input at LASP instead of the custom output provided by the “rack” at Goddard; B) Physically moving the “rack” and interfacing it to the full level zero data stream at LASP; or C), moving operations to LASP but physically leaving the “rack” and CAMMICE/CEPPAD GSE at Goddard and having it “tended to” by the Polar Instrument Engineer as one of his duties. We will explore these alternatives with the CAMMICE/CEPPAD team as well as other approaches they suggest. We will discuss the alternatives and agreed upon solution with the Polar project scientist before proceeding to implement it.

The proposed budget does not include the costs of implementing functionality to replace that currently provided by the VIS, CAMMICE, and CEPPAD GSE's at Goddard.

3.5 Continuation of NRT data stream:

We will adapt existing code and implement it on computers at LASP to produce Polar and Wind LZ data products from real time (not tape recorder data) and provide them over the internet in the same format with the same protocols currently implemented on the ISTEP VAX at Goddard. We will implement this procedure on a Unix box, so details of the interface, such as the username/password protocol, will be different. Some modification of

the nrt data interfaces will have to be done by the PI teams. As noted in Section 3.4 above, we will provide personnel to maintain a high level of availability of the nrt data streams to the Polar and Wind PI sites.

We will provide testing and parallel operation of the nrt data servers to facilitate transition from the ISTP6 server at Goddard to a LASP server.

3.6 Continuation of Quicklook data products:

The Quicklook (QL) data product is a direct production of a level zero file from a tape recorder dump. The tape recorder dump data are physically located at JPL and, with appropriate notification, can be pulled to the ground data processing center. The same software that produces 24 hour level zero data files can produce quick look data files. QL data product differs from the LZ data product only in the file name, start and stop UT (i.e. not generally 00:00), and extra work required to obtain the data from JPL.

The QL data product is therefore best associated with the ground data processing task, not the operations task. If LASP is selected to perform the ground data processing as outlined above, we will provide limited production of QL data products as outlined in the ground data processing section above.

Validation of Operations software and procedures.

Transition of Polar and Wind operations from Goddard to LASP requires translation and interpretation of a large number of codes and procedures. Most, but certainly not all, of the critical information has been documented by the current operations contractor. The risks associated with the transition will, however, be mitigated to a large extent because we do not envision replacing the personnel currently at Goddard and performing Instrument and Payload Engineering tasks under the existing operations contract. We assume that these people will be retained through some tbd mechanism that does not involve LASP. As noted above we are planning to use them to perform the same tasks they are currently performing. The only difference is that their inputs will be from LASP rather than “down the hall.” These individuals are the repositories of most of the undocumented features of Polar and Wind operations.

We will involve these Goddard engineers in the design and translation of the operations. We will provide a detailed and specific plan, in a style similar to a preliminary design review (PDR) to Polar and Wind PI’s as well as Goddard personnel shortly after beginning the development process to make sure that all relevant tasks have been identified and our approach to them is valid. We will host a site review before the interval of parallel operations to further validate the processes and procedures we have implemented. Additionally we will host a second site review about half way through the transition process to make sure that everyone is comfortable with LASP taking on full operations.

Estimate of costs of operations

Costs are shown here as man-months (mm), man-weeks (mw) or full time equivalents (FTE). A summary and translation to \$'s is given at the end of this study.

Development:

Sections of the requirements document

- 1.4 Receiving commands from PI's and Goddard Engineers,
- 2.1 Preparation of spacecraft commanding sequences
- 2.4 Special operations planing and scheduling

Tasks:

- A. In depth examination of system, document accumulation, site visit, preparation of a detailed implantation plan for these tasks 2 mw
- B. Implement and test software and procedures 4.5 mm
- C. Detailed Planning for operations 2 mw
- D. Preparation of training materials for student operators 1 mm

Section 2.2 provide ranging information to FDF 1 mw

Section 2.3 DSN scheduling (we will use existing procedures) nil

Sections of the requirements document

- 3.1 DSN contact with Polar and Wind
- 3.2 Spacecraft Engineering Health and Safety
- 3.3 Payload Engineering Health and Safety

Tasks:

- A. In depth examination of system, document accumulation, site visit, preparation of a detailed implantation plan for these tasks 2 mw
- B. Implement and test software and procedures 4.5 mm
- C. Detailed Planning for operations 2 mw
- D. Preparation of training materials for student operators 1 mm

Section 3.5 Continuation of the NRT data stream for Polar and Wind

- A. In depth examination of system, document accumulation, site visit, preparation of a detailed implantation plan for these tasks 2 mw
- B. Implement and test software and procedures 4.5 mm
- C. Detailed Planning for operations 2 mw
- D. Preparation of training materials for student operators 1 mm

Sub Total 21 mm

Three month Validation/Transition period :

- A. Normal operating personnel at 3.75 FTE 11.25 mm
- B. Software and review support staff 3 mm

Sub Total 14.25 mm

Continuing Operations:

Sections of the requirements document

- 1.4 Receiving commands from PI's and Goddard Engineers,
- 2.1 Preparation of spacecraft commanding sequences
- 2.4 Special operations planning and scheduling

1 FTE

Section 2.2 provide ranging information to FDF nil

Section 2.3 DSN scheduling (we will use existing procedures) 1/2 FTE

Sections of the requirements document	
3.1 DSN contact with Polar and Wind	
3.2 Spacecraft Engineering Health and Safety	
3.3 Payload Engineering Health and Safety	2 FTE
Section 3.5 Continuation of the NRT data stream for Polar and Wind	1/4 FTE
Sub Total	3.75 FTE
Travel Costs: three teams of 2 people 1 week each at Goddard	
	~15k\$
On going materials , telephone, etc. costs	~5k\$/year
Required additional hardware:	~30k \$
Our current estimate is that we will require a some additional data storage, and perhaps two new CPUs. This will be in the range 10-40k\$, the requirements will be better defined after the implementation plan is completed. For guestimating purposes we have put \$30k	

The proposed budget does not include the costs of implementing functionality to replace that currently provided by the VIS, CAMMICE, and CEPPAD GSE's at Goddard.

Proposed schedule for implementing operations at LASP

Software Development starts	2/1/2002
Software Implementation plan distributed	4/1/2002
Review by mail completed	5/1/2002
Software Implementation completed	2/1/2003
Review before transition operations	2/15/2003
Validation/Transition begins	3/1/2003
Mid transition review	4/15/2003
Transition to LASP ground data processing	6/1/2003

Summary of tasks in the requirements document that LASP does not feel it can efficiently take on in the near term.

1: Science Operations Planning

1.1 Event identification, As noted in the requirements document this will become completely a PI function.

1.2: Definitive Orbit Information will not be produced for Polar or Wind as noted in the requirements document.

We will not produce polar platform attitude data files, predictive or definitive. These files are used by the three imaging investigator teams, require specific and detailed knowledge of the platform operation and operational history. Production of these files is best done by one of the imaging teams.

1.3. Polar Despun Platform Pointing Planning.

We will work with the group or individuals who generate the Polar despun platform planning files to ensure that they have timely access to the Polar orbit and attitude files required for their work. These files are used by the three imaging investigator teams, require specific and detailed knowledge of the platform operation and operational history. We *will not* produce them.

3.4 Maintenance of Instrument GSE's: As noted in the discussion above the requirements these GSE's meet can be met in alternative ways. We will explore with the affected Polar PI science teams (VIS, CAMMICE, and CEPPAD) as many alternative approaches to meeting their near real time data requirements by alternate means. The fall back position is to leave the rack of equipment serving the GSE's and the GSE's in place at the Goddard operations center with required support personnel paid for by the Polar/Wind project.

3.7 Data processing, archiving, and distribution.

To minimize operational complexity, we will maintain files for each data product in only one (1) format. For this reason *we will not* produce sirius level zero files for Geotail or associated SFDU files for any data products.

To minimize complexity remote access to "pull down" data from LASP servers will have only a modest level of security. In particular no provision will be made for restricting access to multiple groups data types to designated PI teams. It will therefore be possible for anyone with access to the server to pull down data from all polar, wind, and Geotail investigations.

3.9 KP Generation:

The po/wi/ge k0_spha files are named as key parameter files. They are actually attitude files and will be produced and distributed as discussed in other sections. Other Key Parameter (KP) files are instrument specific. In particular they require a detailed knowledge of the instrument and its operational history. These data products are best produced by groups with easy and direct access to the many individuals holding undocumented knowledge about the state and operation of the various instruments. We will not undertake the difficult and complex task of porting existing KP software to a new environment.

3.10 Definitive orbit and attitude data.

As discussed in the requirements document, definitive orbit and attitude data for Polar and Wind were discontinued as part of an earlier re-engineering effort. If the responsible NASA officials determine that the predictive orbit and attitude data are inadequate for data analysis, we will process and distributed updated versions of attitude and orbit files as required.

3.11 Ancillary Data Ingestion. We *will not* assemble and pass through to NSSDC data sets other than those from Wind, Polar, and Geotail described above. We do not feel that we can provide any value added services, only costs to this processing.

3.12 Data Distribution

Our initial thrust will be to produce custom CD's for projects associated with LASP Polar investigators (TIMAS/Peterson and CAMMICE/CEPPAD, Baker) using data analysis funds available to them. On request of , and with appropriate supplemental funding from, the Polar project scientist, we will make similar custom CD's for other Polar PI teams. We have no plans to make custom CD's for Wind or Geotail investigators.

Summary of important qualifications made above.

- 1) We will not use the Goddard command management system (CMS) system. We will work with operators to extract the most important “rules” captured in this system and implement them in our OASIS-CC software.
- 2) We will not replace the functions of FDF, we will develop interfaces to get and receive information from them
- 3) We will not replace the functions of Spacecraft and Instrument engineers at Goddard. We will develop policies and procedures to provide them with information in a timely manner as well as procedures to ensure that their advise and consent is obtained in a timely manner. In particular we will rely on them for planing and advising on battery management, tape recorder management, thermal management, maneuver planning, and anomaly resolution.
- 4) We will not do Polar despun platform planning
- 5) We will not initially consider implementing processing of instrument specific KP files from LZ data. If the need for this function can not be met by PI teams or other groups we will consider taking it on.
- 6) We will not generate SFDU files
- 7) We will not generate sirius files
- 8) We will not support “pushing” files to PI sites using scripts running at LASP. Investigators will have to pull their data from our ftp sites.
- 9) The proposed budget does not include the costs of implementing functionality to replace that currently provided by the VIS, CAMMICE, and CEPPAD GSE's at Goddard. We will work with the PI teams to meet their needs to near real time data currently met by the GSE's. An extensive discussion of the options and fall back position is given above.
- 10) To the extent possible, we will use a “lights out” approach to data acquisition. We will also try to work to 3 Polar and less than 1 Wind contact per day to more fully use the available tape recorder capacity . The budget and schedule above are based on 4 Polar and 1 Wind contacts per day.
- 11) We will not participate in ancillary data ingestion. It does not make sense for us to put an additional layer between data providers and the CDAWeb.
- 12) The primary SORCE for assistance to PI teams in building commands in response to instrument anomalies will remain with instrument engineers at Goddard. We will assist instrument engineers and PI teams as required to generate new command sequences in response to instrument anomalies

Summary of estimated costs:

The estimate below consists of three parts: Development and Test, Transition/Training, and Ongoing operations. We use a mix of students and professionals for both development and operations. Currently this running at a 50/50 mix and the burdened FTE cost is \$110k/yr. For this study we have rounded this off to 10k per month (\$120k/yr).

Estimate of costs of Ground data processing

	75k\$ development and transition
	65k\$ yr production
	plus 3k\$ hardware
Development:	5 man months
Validation/Transition:	2 man months
Production Processing:	1/2 FTE
Other:	
Travel Costs: 2 people 1 week at Goddard	~5k\$
On going materials costs	~5k\$/year

Estimate of costs of operations

	414.5k\$ development and transition
	455k\$/yr production
	plus ~30k\$ hardware
Development:	21 man months
Three month Validation/Transition period	14.25 man months
Continuing Operations	3.75 FTE
On going materials , telephone, etc. costs	~5k\$/year
Other costs	
Travel Costs:	~15k\$